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NOTE ON THE USE OF HAIL INSURANCE DATA FOR THE EVALUATION OF HAIL SUPPRESSION TECHNIQUES

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by

P.W. Summers

Research Council of Alberta
Edmonton, Alberta
1966

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RESEARCH COUNCIL OF ALBERTA

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P.W. Summers

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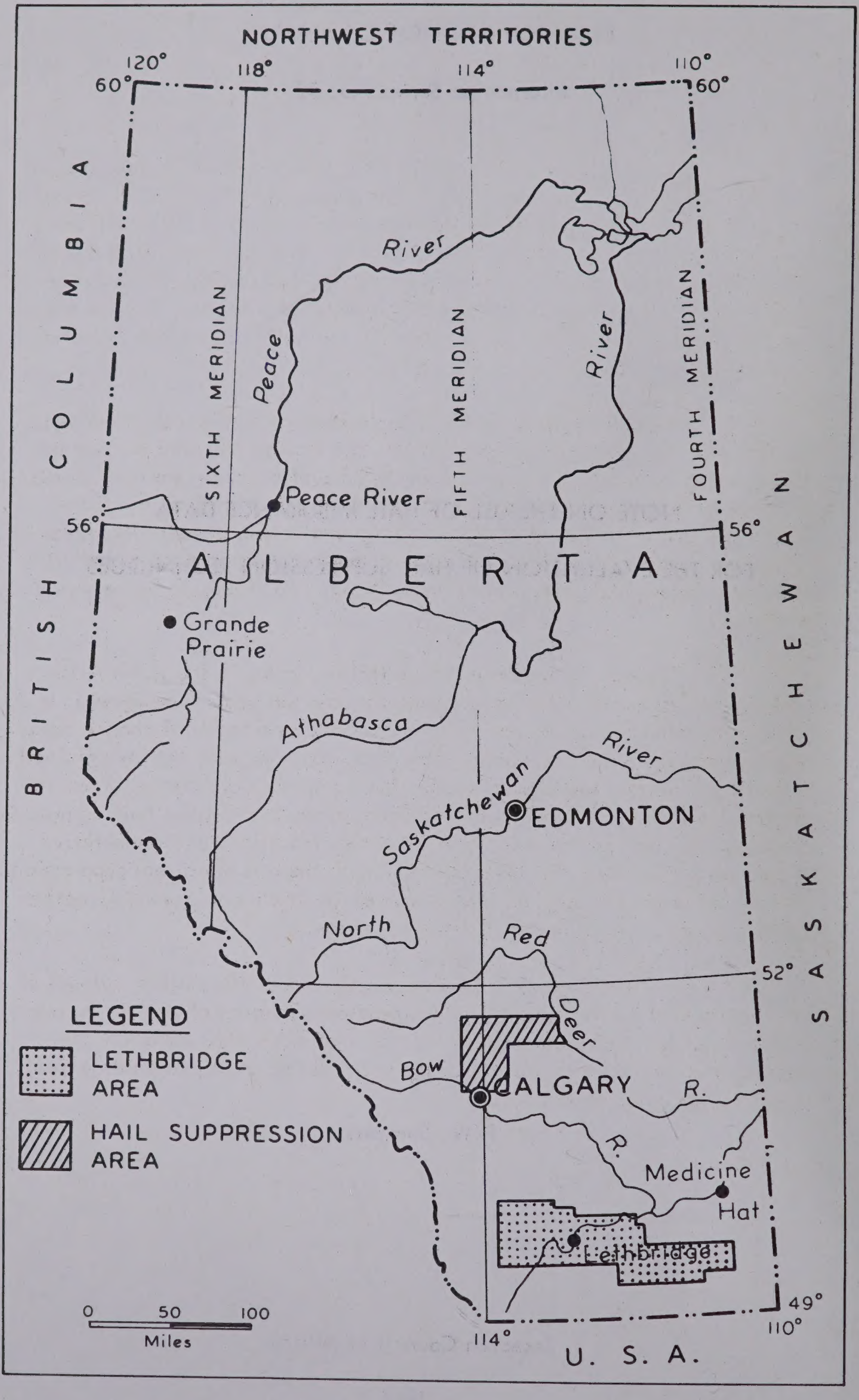

Figure 1 Map of Alberta showing the hail suppression area and the Lethbridge area.

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ERRATA

Page 8. Read "... of 8.89 almost equal to the mean value of 11.96" (not "... of 11.9 almost equal to the mean value of 12.09")

Page 19. Read the third equation as:

$$\sigma^2 = \frac{(N - 1)S_N^2 + (n - 1)S_n^2}{N + n - 2}$$

A large variation in the loss-to-risk ratio is evident from year to year and this variation becomes larger, the smaller the area considered. This is a consequence of the natural variability of hailstorm activity in the province. In fact, this variability of hailstorms, both in time and space, is so large that a statistical approach to the evaluation of hail suppression techniques, either by "target-control" regression analysis or by time-series analysis using yearly mean loss-to-risk ratios, is not likely to be very rewarding.

There is an apparent substantial reduction in the loss-to-risk ratio in the hail suppression area during the last ten years. However it is shown that this could quite easily have occurred as a result of chance natural fluctuations in storm activity. This fact, together with the unexplained reductions observed elsewhere, means that no conclusions can be drawn regarding the effectiveness or ineffectiveness of the commercial hail suppression program operated by the Alberta Weather Modification Co-operative. It must be emphasized that this does not imply there is not a real suppression effect, but rather, if such an effect does exist, it cannot be readily detected by a study of yearly mean loss-to-risk ratios.

In conclusion it is pointed out that some alternative methods of evaluation must be found both for the immediate purpose of evaluating present commercial hail suppression programs, and even more important, as a necessary prerequisite to the sound scientific design of any research experimentation on storm clouds.

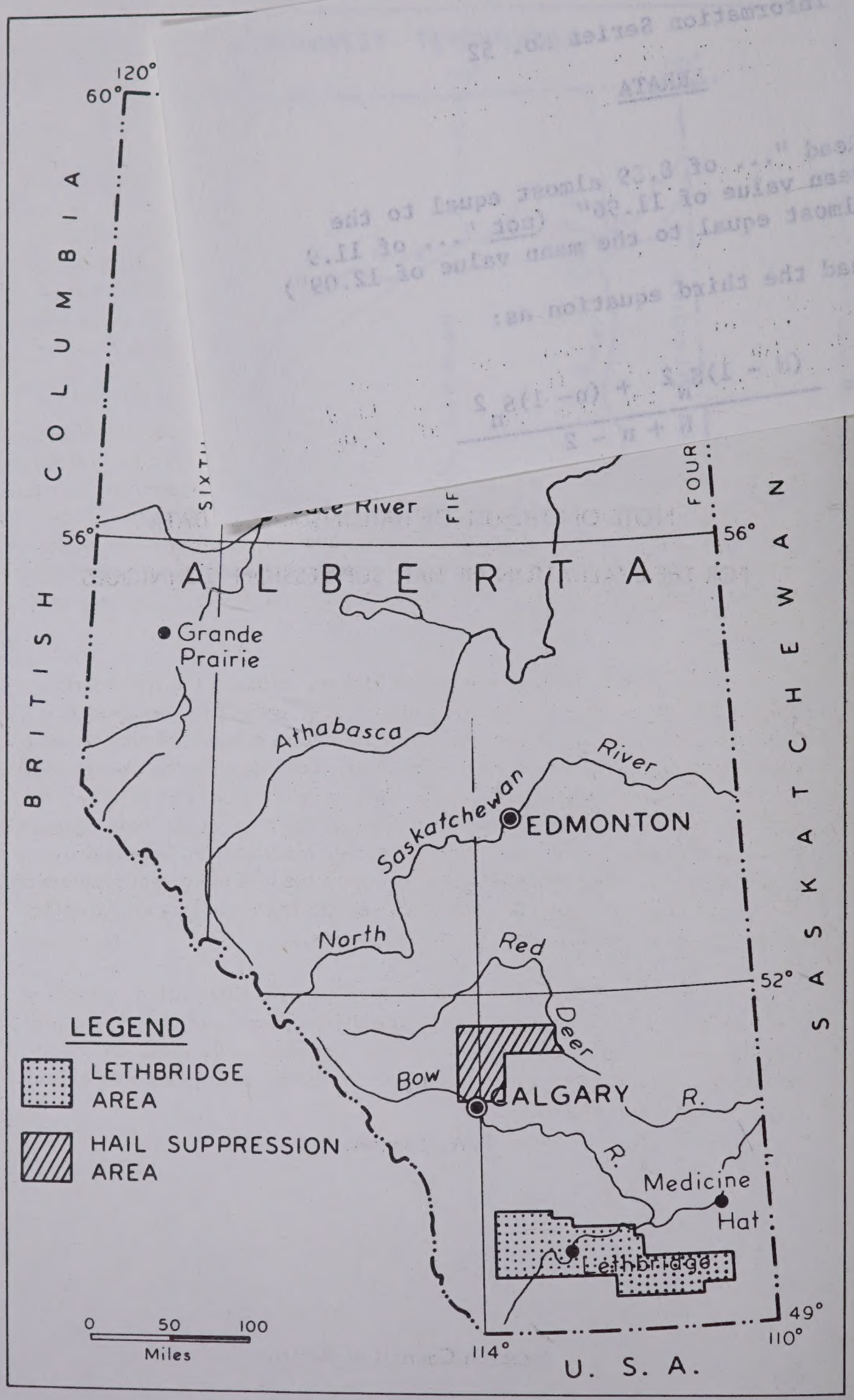

Figure 1 Map of Alberta showing the hail suppression area and the Lethbridge area.

ABSTRACT

A brief study is made of the data from the Hail Insurance Board of Alberta (1919-1936) and the Alberta Hail Insurance Board (1938-1965) available on hail damage for the province back to the year 1919. These data indicate an, as yet unexplained, gradual downward trend in the loss-to-risk ratio for the whole province commencing about 1930, the average over the last ten years being the lowest since records began. A more pronounced downward trend is also observed in the Lethbridge area, but commencing in the early 1920's.

A large variation in the loss-to-risk ratio is evident from year to year and this variation becomes larger, the smaller the area considered. This is a consequence of the natural variability of hailstorm activity in the province. In fact, this variability of hailstorms, both in time and space, is so large that a statistical approach to the evaluation of hail suppression techniques, either by "target-control" regression analysis or by time-series analysis using yearly mean loss-to-risk ratios, is not likely to be very rewarding.

There is an apparent substantial reduction in the loss-to-risk ratio in the hail suppression area during the last ten years. However it is shown that this could quite easily have occurred as a result of chance natural fluctuations in storm activity. This fact, together with the unexplained reductions observed elsewhere, means that no conclusions can be drawn regarding the effectiveness or ineffectiveness of the commercial hail suppression program operated by the Alberta Weather Modification Co-operative. It must be emphasized that this does not imply there is not a real suppression effect, but rather, if such an effect does exist, it cannot be readily detected by a study of yearly mean loss-to-risk ratios.

In conclusion it is pointed out that some alternative methods of evaluation must be found both for the immediate purpose of evaluating present commercial hail suppression programs, and even more important, as a necessary prerequisite to the sound scientific design of any research experimentation on storm clouds.

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NOTE ON THE USE OF HAIL INSURANCE DATA FOR THE EVALUATION OF HAIL SUPPRESSION TECHNIQUES

Introduction

In the summer of 1956 a group of farmers in south-central Alberta obtained the services of I.P. Krick and Associates to conduct a hail suppression program by means of silver iodide cloud seeding. The region covered by this program has varied considerably from year to year, but all or most of the area shown in figure 1 has been included in the region under protection each summer, and for the purposes of this study will therefore be considered as the suppression area. The area consists of 50 complete and 8 partial townships defined as follows: Tps. 24 to 28, R. 27, W. 4th to R. 2 W. 5th plus Tps. 29 to 31, R. 21, W. 4th to R. 2 W. 5th. This amounts to approximately 1900 square miles located in the "hail belt" of Alberta where the most severe storms occur with greatest frequency as evidenced by hail insurance premiums as high as 20 per cent. This hail suppression program has generated a considerable amount of controversy over the years. Much of this controversy has revolved around the evaluation of the effects of cloud seeding, with both sides presenting figures to support their claims of the effectiveness or ineffectiveness of the suppression program. These figures have included yearly mean loss-to-risk data supplied by the Alberta Hail Insurance Board (AHIB). In this note a critical look is taken at some of the hail-damage statistics to see if these loss-to-risk ratios do, in fact, represent a reasonable approach to evaluation, and if so, what use can be made of them.

Hail insurance statistics available

The AHIB underwrites between 60 and 80 per cent of the hail insurance in Alberta each year, but it is estimated that no more than 10 to 20 per cent of the farmers actually insure against hail loss. Records are readily available on a year-by-year basis for each township of the province back to 1919, except for 1937. The old Hail Insurance Board of Alberta was reorganized into the present Alberta Hail Insurance Board in 1937 after the system of collecting premiums gradually broke down in the 1930's. The records contain such information as the number of farmers insured, the area insured, the risk insured, the number of acres damaged and the loss sustained. The most useful parameter for assessing the hail damage is the loss-to-risk ratio (L/R). This is simply the estimated loss divided by the risk insured, and although strictly a ratio, it is by convention multiplied by one hundred and expressed as a percentage. An L/R of zero means no damage to insured crops, and an L/R of 100 per cent means complete loss of insured crops. The L/R for any given region in any given year is, therefore, a combined measure of both the areal extent and the intensity of the storms within that region. In theory it should be possible to assess the effectiveness of a hail suppression program by a study of the yearly mean L/R in the region. The long-term behavior of the L/R will now be considered for three regions — a large area (the whole province) and two small areas (the suppression area and the Lethbridge area as shown in figure 1). Statistics prepared from data supplied by the AHIB for all of these areas are given at the end of the report in appendix A. It will be noted that some of these figures differ somewhat from those given in a preliminary unpublished report. These differences are due to the slightly different, but more accurately defined, suppression area being considered in this report.

Annual variation of L/R for the whole province

A time-series showing the yearly mean L/R for the whole of Alberta is shown in figure 2a. The most striking feature of this time-series is the large variation of the L/R from year to year. This variation has shown a reduction in more recent years. The standard deviation of the L/R for the period 1919 to 1936 was 4.41, dropping to only 2.47 for the period since 1938.

Also shown on figure 2a is the 10-year running mean value of the L/R, indicating an interesting long-term downward trend commencing about 1930 and continuing to the present time. There are several hypotheses that can be suggested as possible explanations for this downward trend:

(a) The change in the organization and operation of the insurance scheme in 1937 may explain the rather rapid fall-off in the L/R about that time. The more gradual fall off since then could be due to steadily improving methods of assessing damage.

(b) The extension of farming, and hence insurance, into areas less susceptible to hail damage (such as the Peace River area), thus lowering the over-all provincial L/R ratio.

(c) A change in the type of crops grown, or an increasing resistance of the crops to hail damage in more recent years.

(d) A long-term climatic change producing a slowly decreasing amount of hailstorm activity in the province. Two of the possible reasons for this could be;
    (i) a change in the large-scale weather pattern in western Canada;
    (ii) local changes caused by man's activities altering the moisture retaining and/or evaporative properties of the soil, or changing the number of freezing and/or condensation nuclei in the atmosphere.

(e) The amount of risk written could influence the resultant L/R. This possibility will be investigated further in the section on insurance data as a measure of hail damage.

It is impossible to ascertain, without a much expanded study which, if any, of these hypotheses are the more likely. However a study of the behavior of the L/R for smaller areas may shed further light on the matter.

Annual variation of L/R in the hail suppression area

The area considered is shown in figure 1, and the yearly mean L/R figures are plotted as a time-series in figure 2b. The year-to-year variation in L/R is even more striking than for the whole province with the standard deviation for the period 1919 to 1955 of 11.9 almost equal to the mean value of 12.09 (see table I). There is no significant reduction in the variation since 1938 as observed in the whole province. The ten-year running mean value of L/R shown on figure 2b smoothes out some of the variations, but is still rather erratic and does not appear to have any long-term trend. The few high peaks in the yearly mean L/R are so far above the mean value that their inclusion or exclusion from any ten year period causes significant discontinuities in the running-mean value.

Relation between the suppression area and the remainder of the province

In the past, attempts have been made to evaluate the effects of hail suppression by comparing the suppression area with the remainder of the province. The validity of this approach is now considered. The time-series for the L/R in the remainder of the province is shown in figure 2c. This graph is very similar to figure 2a and is due to the fact that only a very small percentage of the total provincial insurance is written in the suppression area. Thus subtracting this amount from the whole province leaves the remainder essentially unchanged. Figure 3 shows a scatter diagram with the L/R in the suppression area plotted against that for the remainder of the province. The scatter of points is very large and the correlation coefficient of the L/R in the two areas for the unseeded period is only 0.26. This correlation is too small for a meaningful regression type of analysis using the remainder of the province as a "control" to evaluate hail suppression.

As a matter of interest, the points for the seeded years are included in figure 3. All of these years, except one, lie well within the general scatter of points and hence no conclusion can be made regarding the effectiveness of seeding. The one exception suggests that the L/R in the suppression area was higher than expected on the basis of past history.

Annual variation of the L/R for the Lethbridge area

The AHIB has made data available for a block of 127 townships from Claresholm southeast across Lethbridge to Formost as shown in figure 1. This is in a relatively low risk area with insurance premiums ranging from 5 to 10 per cent. The time-series of L/R for this area is shown in figure 2d. Again there is a large variation from year to year with the historical period 1919 to 1955 having a mean L/R of 5.63 and a standard deviation of 5.59. There is a very pronounced long-term downward trend showing up in the ten-year running mean. The ten-year average L/R in recent years has been running as low as one-quarter to one-third of what it was back in the 1920's.

A scatter diagram for the L/R in the suppression area versus the Lethbridge area is shown in figure 4. The correlation between the two areas is only 0.03 which is much too small for a regression type analysis using the Lethbridge area as a control to evaluate hail suppression.

In order to gain a little more insight into the lack of correlation between the yearly mean L/R in two areas, the frequency distribution of the L/R will now be considered in some detail.

The frequency distribution of yearly L/R for various sized areas

The percentage frequency of occurrence of the yearly mean L/R in 2 per cent class intervals for various sized areas is shown in figure 5. For the large areas consisting of the whole province and the remainder of the province the frequency distribution is a somewhat skewed Guassian, with a slightly longer tail on the right than on the left. The Lethbridge area shows a shift in the modal frequency to the left with an extension of the tail to higher values of L/R. Halving the area to 58 townships shows the same modal frequency but the tail extends further to the right. Data was made available for two 3-township blocks within the suppression area and the frequency distribution shown in figure 5e now has a very high modal frequency at the zero to 2 per cent interval of L/R, of which 33 per cent are actual zero L/R. The tail now extends well to the right with a L/R as high as 70 per cent being reported in a 3-township block in one year. From the data for each township in the suppression area during the years 1919 to 1936 the frequency of occurrence of L/R is shown in figure 5f. The frequency of a L/R less than 2.0 per cent is now over 50 per cent and there is also a second peak beginning to show up at 100 per cent. The distribution is now changing to a U-shape.

The only data available on a smaller unit than a township are the individual claim records. The unit of area is not constant, but is now an insured crop unit varying in size from a few acres up to 160 acres with an average size of about 60 acres. The damage claims for the whole province for 1964 were examined and the resultant frequency distribution is shown in figure 5g. Now the probability of less than 2 per cent L/R is over .95 with the next most likely event 100 per cent L/R with a probability of 0.05. Any L/R between occurs with almost equal probability. The gaps between 90 per cent and 100 per cent L/R and in the low frequencies less than 10 per cent are due to the rounding off methods in assessing damage and adjusting the claims. The distribution is again tending towards a U-shape.

In summary then there appears to be a gradual transition in the frequency distribution of L/R from near Guassian for large areas, through a Poisson type for smaller areas (somewhere between 3 and 58 townships in size) to a U-shape for areas of 1 township and less. This is a consequence of the random distribution of hailstorm patterns in Alberta. There are always some damaging storms somewhere in the province every year. Some years activity is greater than others as shown in figure 2a, and the net result is a near Guassian frequency distribution of L/R over the years as shown in figure 5a. As the area considered becomes smaller the chances of a storm hitting in any one year becomes less and less, but at the same time the chances of getting a high L/R in those years that a storm does hit also increases. This point is illustrated in figure 6 based on a study of 6 different sized areas. The number of occurrences of zero L/R is used to estimate a probability. In the case of the suppression area no years out of the total of 46 recorded a zero L/R thus the probability is estimated at less than .02. The data in figure 6 are taken from different periods of time and different parts of the province, but do show a striking relationship between area and probability of a zero L/R occurring. The exact relationship could be determined more accurately by considering a fixed area (e.g. 16 x 16 townships) in the centre of the province and successively breaking it down into smaller and smaller blocks.

Although there appear to be certain preferred areas for hailstorms in Alberta, the storm tracks are essentially random depending on the point of origin and the steering upper wind flow. One would therefore expect little correlation between the occurrence of storms in two separate areas, and the smaller the areas, the less likely for a severe storm to occur in both during the same year.

The L/R ratio during the seeded period

Since a comparison of the individual yearly mean L/R ratios in two areas by a regression type analysis is ruled out by the discussion in the previous section and the poor correlations illustrated in figures 3 and 4, the time-series approach will be considered in more detail. Returning to figure 2b there is an apparent reduction in the L/R since 1956 compared to preceding 36 years. How big is this reduction, and is it statistically significant? The reduction in the L/R during the last 10 years is 37 per cent as shown in table I; however, by applying the standard statistical test for the significance of the difference in the mean value of two independent samples (see appendix B), it can be shown that the probability of this reduction occurring by chance is 0.16. In other words the reduction is far from being statistically significant and could have resulted quite readily from chance natural variations in hailstorm activity. Also table I shows that a similar reduction of between 30 and 40 per cent has occurred in the whole province as well as in the Lethbridge area. In fact it is only for the province as a whole that the reduction is anywhere near statistical significance, because of the small standard deviation. As a point of interest the reduction of 37 per cent observed in the suppression area would have to continue for a total of approximately 20 years before it would become significant at the 5 per cent level. On the other hand if the L/R were reduced to one half of the average pre-seeding value, this would become statistically significant in about 7 to 10 years.

But even if the reduction in the suppression area turned out to be statistically significant, extreme care would be required in assuming a causal relationship with cloud seeding, until the statistically more significant reduction elsewhere had been satisfactorily explained.

Although the 10-year running mean is a useful tool for smoothing out some of the large variations, and for showing up general long-term trends it cannot show sudden changes in regime, or trend, because each point is influenced by the five years on either side. Another way of looking at the time-series shown in figure 2 is to compute the mean value for the whole period and the deviation of each year from this mean. These deviations can then be accumulated to give the graph shown in figure 7. The slope of the curve from one point to the next indicates whether the second point is near, above or below the long-term normal. A continually rising curve such as shown from 1927 to 1931 in figure 7a indicates a prolonged period of 5 years during which every year was above normal. The curve for the whole province shown in figure 7a breaks down into four well defined regimes:

1919-1926	near normal L/R
1927-1931	above normal L/R
1932-1947	near normal L/R
1948-1965	mainly below normal L/R

An exactly similar breakdown occurs for the remainder of the province. The Lethbridge area (figure 7b) breaks down into only three regimes as follows:

1919-1929	mainly above normal L/R
1930-1947	near normal L/R
1948-1965	mainly below normal L/R

There is a remarkable similarity between the regimes observed in the Lethbridge area and the whole province apart from the first 10 years.

The suppression area (figure 7c) shows a very different pattern, with a cyclical pattern of alternating periods of above and below normal L/R lasting between 3 and 12 years. Note that the last major reversal to a regime of below normal L/R occurred in 1955 — one year before cloud seeding for hail suppression was commenced.

Also note that in all three curves there is no change in regime in 1937 at the time when the insurance scheme was reorganized. This suggests that the regimes are not dependent on the insurance scheme, and justifies the use of all past data on hail damage rather than just the years since 1937.

Insurance data as a measure of hail damage

It is estimated that only 10 to 20 per cent of the farmers in Alberta take out hail insurance. Is this enough to give an unbiased estimate of the actual hail damage that occurs? If the insured farmers were randomly distributed, then there is no obvious a priori reason why the observed L/R in a given region should not give a reasonable estimate of the true percentage damage in the region. But if the number of farmers taking out insurance dropped below a certain critical level, then it is possible that a storm could pass through an area without hitting any insured crops; the recorded L/R of zero would then not be a good estimate of the actual damage.

The effect of the amount of risk written in a township on the resultant L/R recorded was investigated empirically as follows. The original Hail Insurance Board of Alberta data from 1919 to 1936 for the suppression area were studied. The risk was stratified into 6 class intervals selected so that there would be approximately an equal number of observations in each interval. The number of zero L/R ratios and the total number of observations in each interval are shown in table II. It can be seen that the risk does in fact very strongly influence the probability of recording a zero L/R, with the probability increasing rapidly as the risk becomes smaller, particularly under $10,000. Thus any marked changes in the amount of risk written in a region may influence the recorded L/R. For example this may be a factor in the observed reduction in L/R in the suppression area over the last 10 years because the risk written has dropped by nearly one half to an average of $8,400 per township from the previous long-term average of $15,300 per township.

The amount of risk written for the whole province has shown a general increase, with interruptions, since 1943; but it is not known whether the average number of townships in which insurance is written has risen at the same, a faster or a slower rate. Thus it is impossible to say whether the average risk written per township has changed over the years.

Another major disadvantage of using a L/R ratio is that ratios are not additive in the strict sense, as with the compute average values shown in table I. To take an extreme case consider two adjacent townships. In township A the risk written is $10,000 and in township B the risk written is $100,000. If a storm goes through township A only, it could easily hit the one or two farms which have insurance and give a loss of $10,000 for a L/R of 100 per cent. The arithmetic mean L/R for the two township area would then be 50 per cent but the true weighted L/R would be $10,000 divided by $110,000 giving only 9 per cent. Likewise a major storm could wipe out all the crops in township B only giving a L/R of 100 per cent. The arithmetic mean L/R for the two township area would again be 50 per cent, but the true weighted mean would be $100,000 divided by $110,000 giving 91 per cent. These are extreme cases but in view of the large variations in risk written from year to year (see appendix A) considerable differences could arise between the arithmetic mean L/R over a period of years and the true L/R.

Finally any effects from weather modification programs elsewhere in the world either have been undetectable or, at the most, have amounted to changes of only a few per cent. There is also theoretical and observational evidence to suggest that cloud seeding as currently practised is likely to have a detectable effect only under certain suitable but rather limited conditions. Thus if cloud seeding were effective in reducing hail only on some of the storms in the summer, this effect would be diluted by inclusion of all storms in the analysis; or may even be cancelled by a reverse effect on some storms such as occurred in Argentina (Iribarne and Grandoso 1965). Hence the use of yearly mean values of L/R automatically makes it even more difficult to detect any real effects, either positive or negative, that may be present.

Conclusions and recommendations

The preceding analysis shows that, for many reasons, a statistical approach using AHIB data for the evaluation of either commercial hail suppression or scientific experiments is fraught with difficulties and is not likely to be very rewarding. The main problems involved are summarized below:

(a) Firstly, how reliable is the data? Does it give an unbiased estimate of the true L/R for an area? How dependent is the L/R on the size of the area studied, or the amount of risk written? An initial look at these questions was taken in section 9, but for complete answers a much more detailed study would be required.

(b) Secondly, even if the data were reliable or could be normalized to some standard risk, there would still be the problem of the semi-random space and time variations of hailstorms. This makes a "target-control" correlation very small and useless for a regression type analysis. Also a time-series approach is unlikely to be useful unless either the reduction in hail damage due to seeding is very large or the reduction continues for an inordinately long period of time.

(c) Thirdly, the L/R ratios in the whole province and at least one other small area show some interesting trends, with the mean value of the L/R during the last 10 years down from the long-term normal by a percentage similar to that observed in the suppression area. Until these changes can be satisfactorily explained in terms of natural or man-made causes, no conclusions can be drawn regarding the cause of the observed drop in the suppression area. A study of other areas may throw further light on the problem.

It has been suggested that another source of data – namely PFAA payments – may give a better measure of hail damage. It is true that this data gives more complete coverage, since claims are settled on the basis of losses incurred, irrespective of whether the farmer insured or not. However payments are made for damage due to many causes including hail, and it would often be difficult to sort out objectively the effects of hail alone. Also a minimum number of adjacent farms receiving a low enough crop yield to qualify for payments are required. Therefore intermittent, narrow swath type storms common in Alberta may not cause the necessary damage pattern to ensure qualification for payment. But even if the PFAA payments were a more reliable measure of the true hail damage than AHIB data, the problems raised in paragraphs (b) and (c) above would still have to be faced.

These conclusions agree with those presented by Schleusener et al. (1965), after a thorough statistical analysis of hailfall parameters measured in Colorado by simple aluminum foil hail detectors. These parameters were much more objective than either AHIB or PFAA hail damage data, yet the conclusions were as follows:

(1) Lack of significant correlation between adjacent areas indicates that a target-control analysis is not feasible for attempting to detect significant changes that might result from a hail modification experiment.

(2) The sequential analysis test alone could not adequately evaluate the effectiveness of this hail modification experiment.

However, because of the more precise data obtained it was felt that two of the parameters considered could be used to detect scale changes of 10 to 25 per cent (if they exist) in a period as short as 3 to 5 years. These parameters are the square root of the total number of hailstones falling per unit area and the logarithm of the impact energy of the hailfall.

One alternative to a statistical evaluation of hail reaching the ground is an evaluation of physical changes within the clouds. In this case a detailed study is made of individual storms. The behavior of seeded storms is analyzed to see if any physical changes can be detected in the cloud which would affect size, structure, and amount of hail falling from the cloud, consistent with the known time, place, and amount of seeding material injected into the cloud. The behavior of nonseeded clouds would be used as a control for comparison purposes. This approach has been used with considerable success by Russian scientists in recent years [Battan (1965), Borovikov et al. (1964)]. However, it is expected that any relationships which show up between hail damage and physical properties of the storm will also be, at least in part, of a statistical nature. For example, one of the simplest physical properties directly measurable is the radar echo top. Based on several years' data obtained by Alberta Hail Studies from the farmers, it appears that a storm having a radar echo top of 34,000 feet above the ground will produce some hail 4 times out of 5, but will produce golfball size or larger hail only 9 times out of 40. Thus for clouds having identical radar echo tops, there is considerable variation in the hail size produced and presumably an even greater variation in damage caused. For a physical evaluation of cloud seeding it is necessary first to find one or more physical parameters which have a small variance, so that any changes induced by experimentation can be detected at a high statistical significance level after a reasonable number of tests. The Russian work indicates that the vertical profile of radar reflectivity may be one such parameter (Borovikov 1964).

The main purpose of this note was to point out some of the difficulties involved in a statistical evaluation of the effectiveness of hail suppression techniques. In addition this study has also brought out the fact that the available data do not show convincing evidence of a statistically valid reduction in L/R in the commercial hail suppression area since 1956. It must be emphasized that this does not imply that cloud seeding has not caused a reduction in hail damage. But it does mean that if such a reduction does exist, it is impossible to detect it using a statistical approach based on AHIB yearly mean L/R figures. Another look could be taken at the time-series approach in a few years time to see if the reduction has continued in the suppression and has become more significant than elsewhere in the province. Until then no conclusions can be made from the present analysis as to the effectiveness or ineffectiveness of the commercial hail suppression program being carried out in Alberta.

In the meantime the whole problem of design and evaluation of experiments is receiving much attention around the world and is one of the five major areas in which advances are desirable both for achieving useful weather modification and for furthering our understanding of the atmosphere [National Academy of Sciences (1966)]. Work on evaluation techniques will therefore be continued by the Research Council of Alberta, because it is essential that a suitable method be evolved before serious consideration can be given to the design of any research experiments on hailstorms.

Acknowledgments

The author wishes to acknowledge the co-operation of the Alberta Hail Insurance Board for making its original records available to compute the data shown in appendix A. The data extraction and tabulations were performed by Mr. Ford Bergwall.

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Table I. Comparison of the loss-to-risk ratio during the last ten years with the long-term historical period for various areas of the province

	HISTORICAL PERIOD 1919-1955		HAIL SUPPRESSION PERIOD 1956-1965		
	Mean L/R (%)	Standard deviation of L/R	Mean L/R (%)	Percent reduction from historical period	Probability of this reduction occurring by chance
Whole province	6.93	3.76	4.59	34%	0.067
Suppression area	11.96	8.89	7.50	37%	0.16
Rest of province	6.54	3.82	4.54	31%	0.12
Lethbridge area	5.63	5.59	3.52	37%	0.27

Table II. Probability of a zero L/R occurring in a township for various values of risk insured (based on years 1919-1936 in the suppression area)

RISK ($)	≤1,999	2,000 to 4,999	5,000 to 9,999	10,000 to 19,999	20,000 to 49,999	≥50,000
No. of obs.	133	106	96	141	260	89
No. of zero L/R	89	62	44	51	58	8
Prob. of zero L/R	.67	.59	.46	.36	.22	.09

APPENDIX A. Statistics prepared from data supplied by the Alberta Hail Insurance Board

LOSS TO RISK RATIO L/R (%)					RISK WRITTEN		
YEAR	Whole prov.	Sup-pression area	Rest of prov.	Lethbridge area	Whole prov. ($\$ \times 10^6$)	Sup-pression area ($\$ \times 10^4$)	YEAR
1919	3.8	4.0	3.8	0.4	13.1	99.1	1919
1920	4.0	16.5	3.1	5.8	21.9	151.2	1920
1921	10.5	24.3	9.2	14.0	20.4	185.6	1921
1922	2.1	3.1	2.0	3.9	14.1	140.8	1922
1923	11.4	8.9	11.7	25.5	21.2	236.4	1923
1924	5.5	6.0	5.4	8.4	8.7	118.1	1924
1925	6.3	2.1	6.9	10.9	10.9	139.6	1925
1926	6.3	13.1	5.4	0.1	10.8	132.7	1926
1927	17.1	26.3	15.8	6.1	14.8	172.0	1927
1928	12.4	8.5	12.9	19.4	12.5	149.3	1928
1929	7.3	25.6	5.4	7.8	7.9	73.1	1929
1930	16.0	4.6	17.0	2.5	11.0	86.3	1930
1931	9.6	14.8	9.3	2.4	1.6	9.3	1931
1932	3.1	1.0	3.2	7.3	2.4	11.8	1932
1933	2.4	1.6	2.4	0.0	1.0	4.8	1933
1934	10.2	1.1	10.9	8.5	1.3	9.3	1934
1935	7.6	21.2	6.4	2.2	1.3	10.4	1935
1936	9.5	14.6	8.8	0.0	1.1	13.5	1936
1937							1937
1938	6.8	20.0	4.9	7.7	7.1	89.8	1938
1939	3.8	14.0	2.4	5.9	10.7	128.4	1939
1940	6.3	2.8	7.0	2.9	7.4	113.1	1940
1941	7.9	16.9	6.4	11.3	5.6	84.0	1941
1942	2.3	3.5	2.2	0.5	9.5	73.5	1942
1943	9.3	24.4	8.3	6.8	5.0	31.3	1943
1944	4.7	7.8	4.5	9.4	8.4	42.3	1944
1945	9.4	19.6	8.6	5.0	10.3	68.0	1945
1946	4.3	12.2	3.9	0.7	17.8	89.6	1946
1947	9.4	4.8	9.7	9.2	18.7	93.6	1947
1948	1.4	6.7	1.1	0.7	14.0	72.9	1948
1949	4.3	12.4	4.1	1.3	10.3	24.6	1949
1950	4.5	2.7	4.5	3.8	17.2	44.0	1950
1951	7.3	16.9	7.1	4.3	29.5	66.3	1951
1952	4.4	7.8	4.3	3.4	26.7	59.2	1952
1953	9.1	35.3	8.6	2.3	26.7	52.4	1953
1954	7.0	22.1	6.4	2.4	14.8	52.7	1954
1955	2.0	3.4	1.9	0.0	14.9	51.8	1955
1956	6.7	11.6	6.6	5.4	15.9	41.3	1956
1957	6.1	14.0	5.9	3.0	12.7	30.1	1957
1958	4.0	0.6	4.1	1.7	13.1	30.2	1958
1959	2.2	22.7	1.9	0.9	17.2	26.3	1959
1960	8.5	8.8	8.5	2.2	16.7	40.8	1960
1961	3.7	2.3	3.7	10.0	10.0	21.4	1961
1962	4.3	3.0	4.3	2.9	18.6	43.2	1962
1963	4.4	4.8	4.4	3.3	22.2	52.2	1963
1964	2.0	3.9	2.0	1.7	25.4	63.5	1964
1965	4.0	3.3	4.0	4.1	36.9	105.4	1965

APPENDIX B. Formulas used in performing statistical tests

The following statistical formulas were used for the computations shown in table I.

Standard Deviation (S) of the L/R is given by:

$$S^2 = \frac{\Sigma x^2}{N - 1} - \frac{(\Sigma x)^2}{N(N - 1)}$$

where x is the L/R for each year and N is the number of years in the sample.

The "Students" t-test was used to test the significance of the difference between the suppression period and the historical period. If N and n are the number of observations in the two periods, and M and m are the mean values of the L/R in the two periods then:

$$t = \frac{M - m}{\sigma\sqrt{\frac{N + n}{Nn}}}$$

where σ is an estimate of the standard deviation of the population from which the samples are believed to have been drawn and is given by:

$$\sigma^2 = \frac{(N - 1)\, S_N^2 + (N - 1)\, S_n^2}{N + n - 2}$$

Where S_N and S_n are the standard deviations of the two periods as given by the first formula.

The probability of the difference between M and m being due to chance is then given by standard "Students" t-test tables with N + n - 2 degrees of freedom.

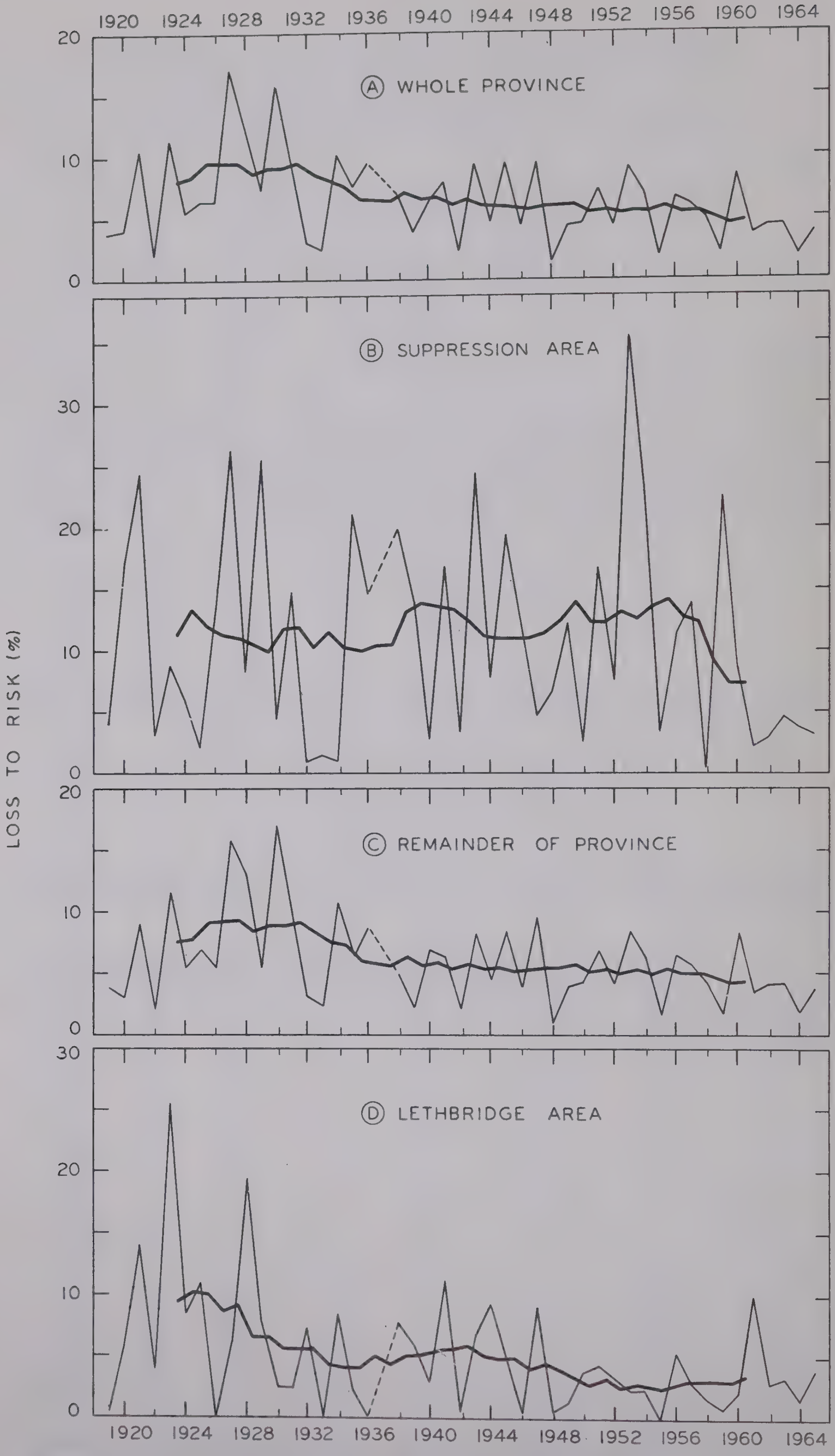

Figure 2 Time-series showing the yearly mean L/R ratios, and the ten-year running mean for various regions.

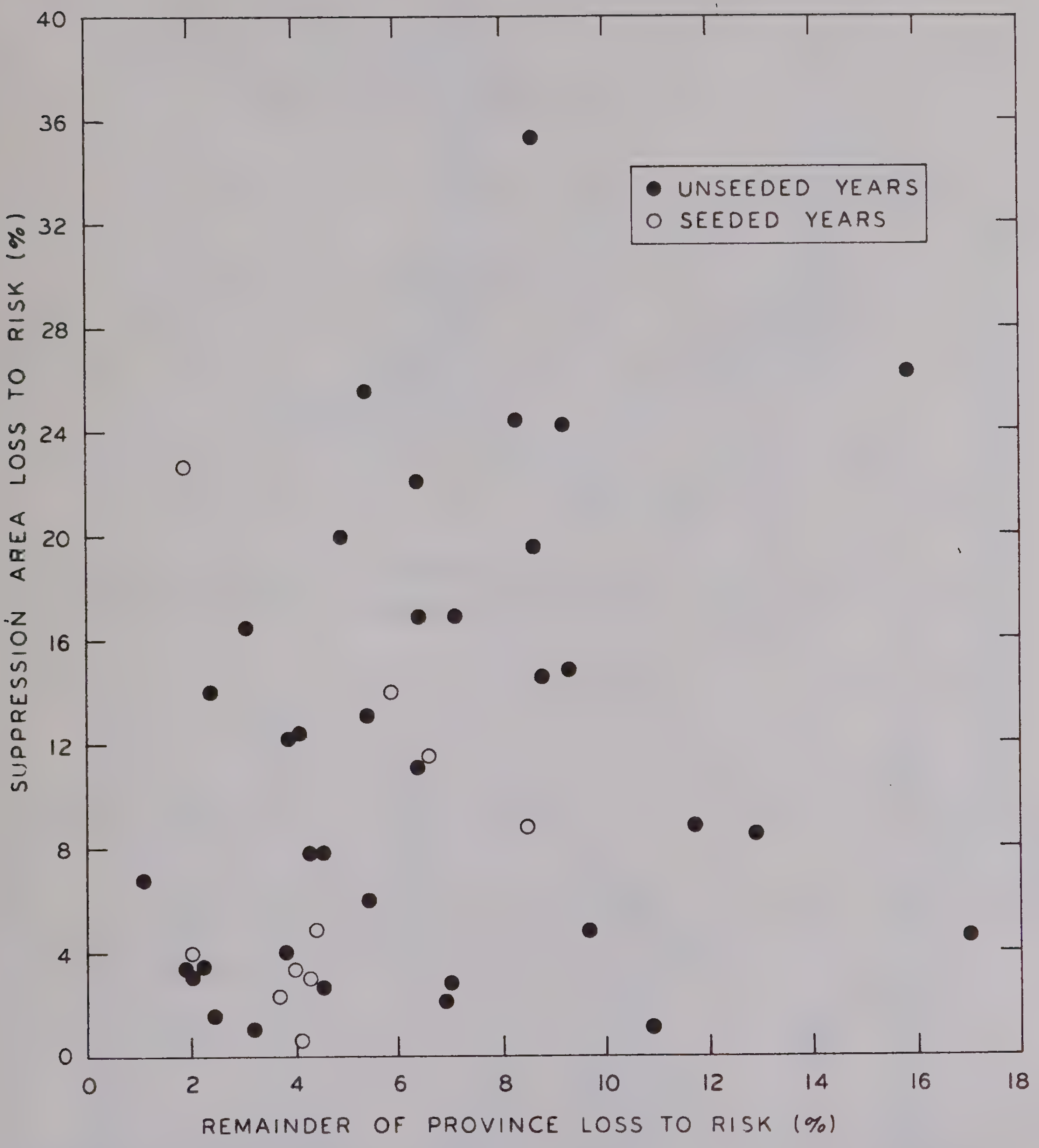

Figure 3 Scatter diagram showing the relation between the yearly mean L/R in the suppression area versus the remainder of the province.

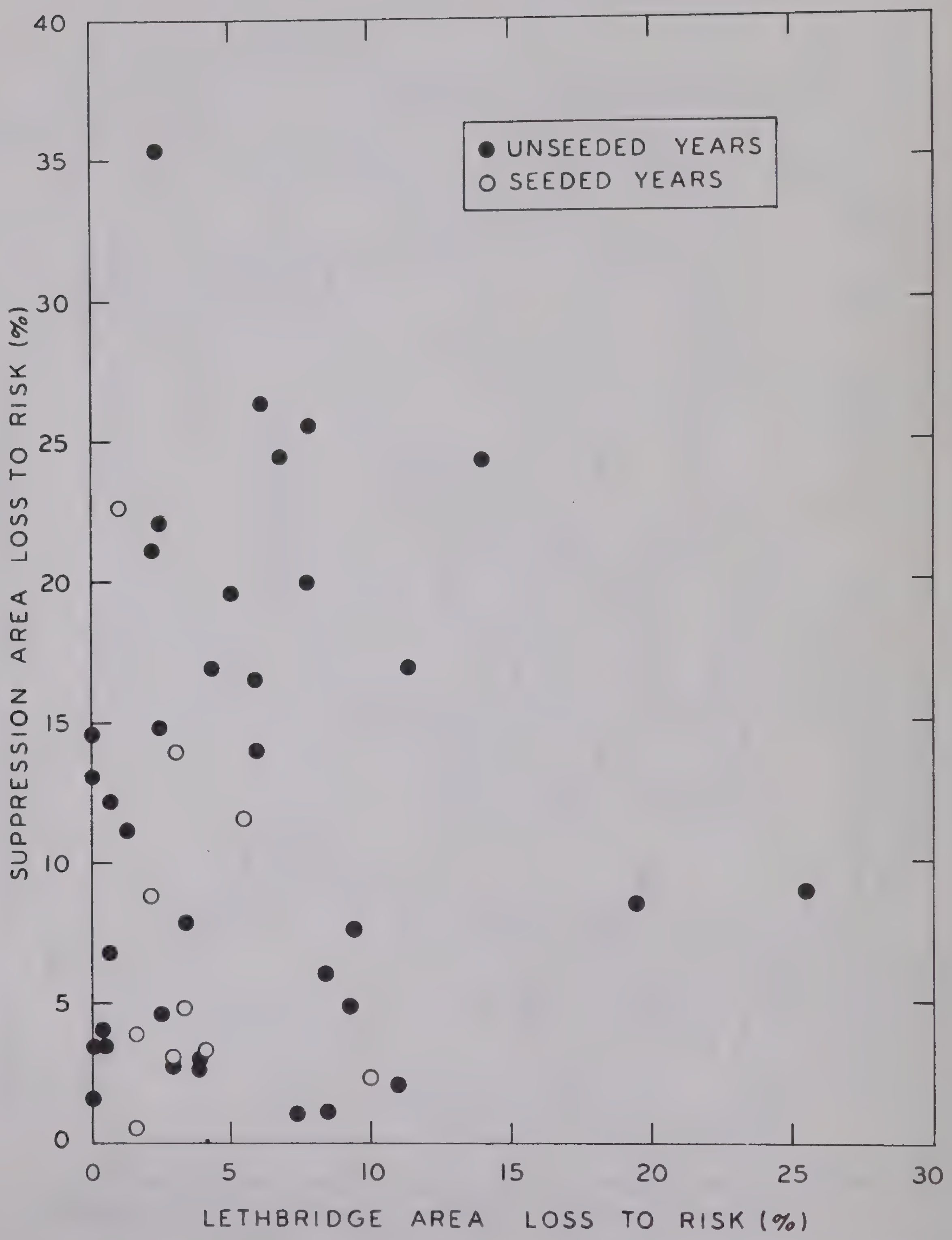

Figure 4 Scatter diagram showing the relation between the yearly mean L/R in the suppression area versus the Lethbridge area.

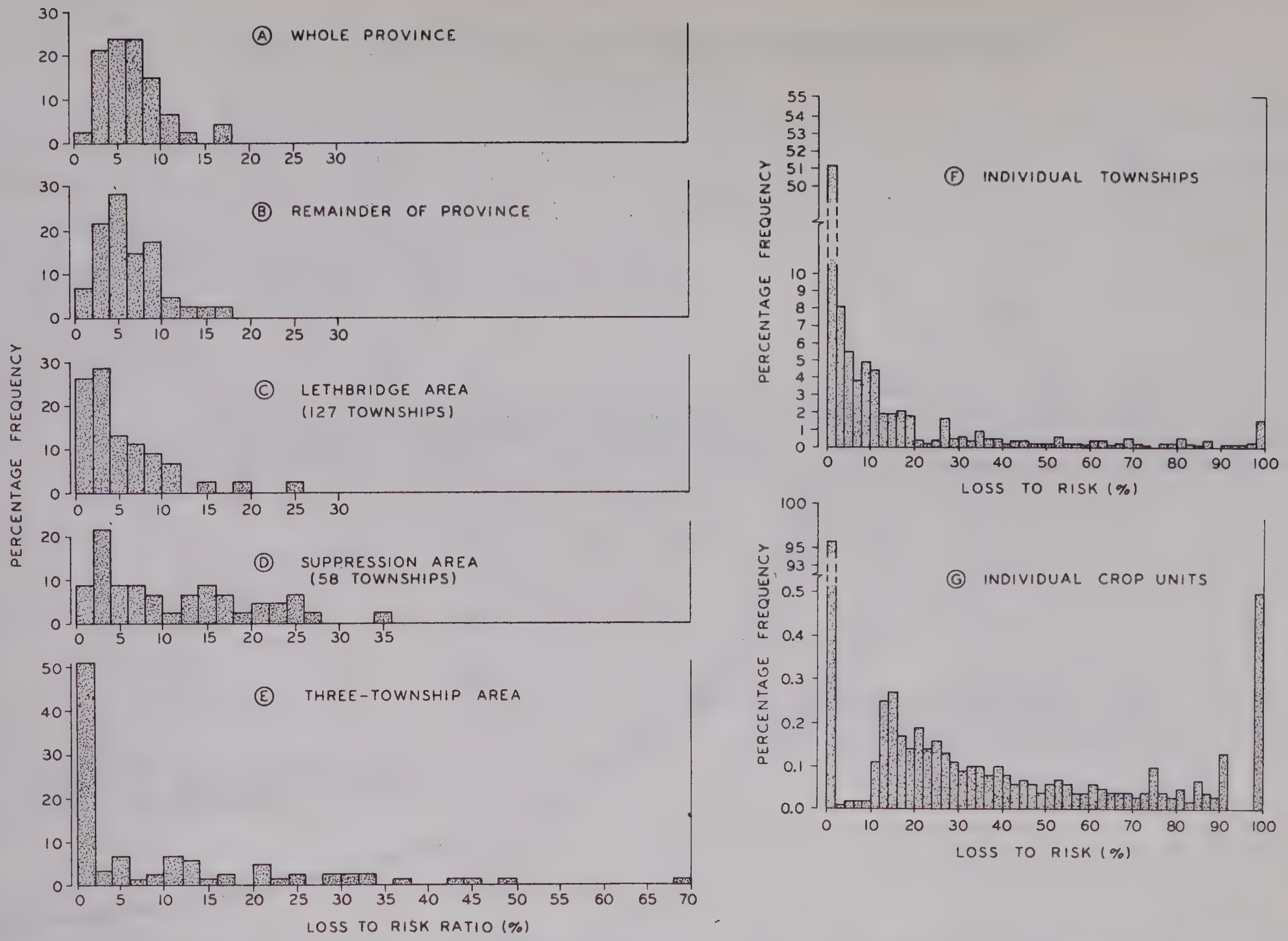

Figure 5 Frequency distributions of the yearly mean L/R ratios for various sized areas.

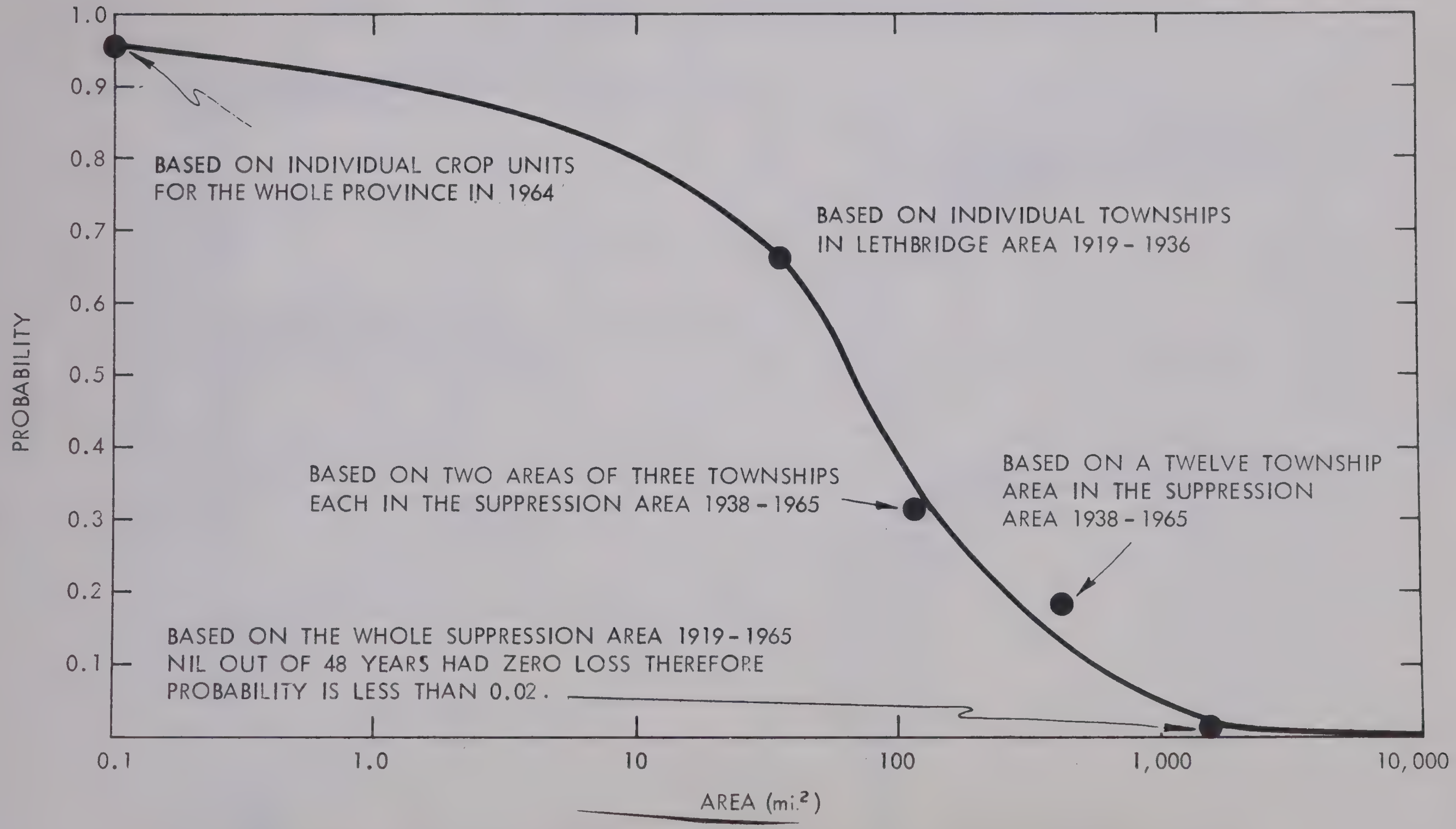

Figure 6 Probability of a yearly mean L/R of zero versus size of area.

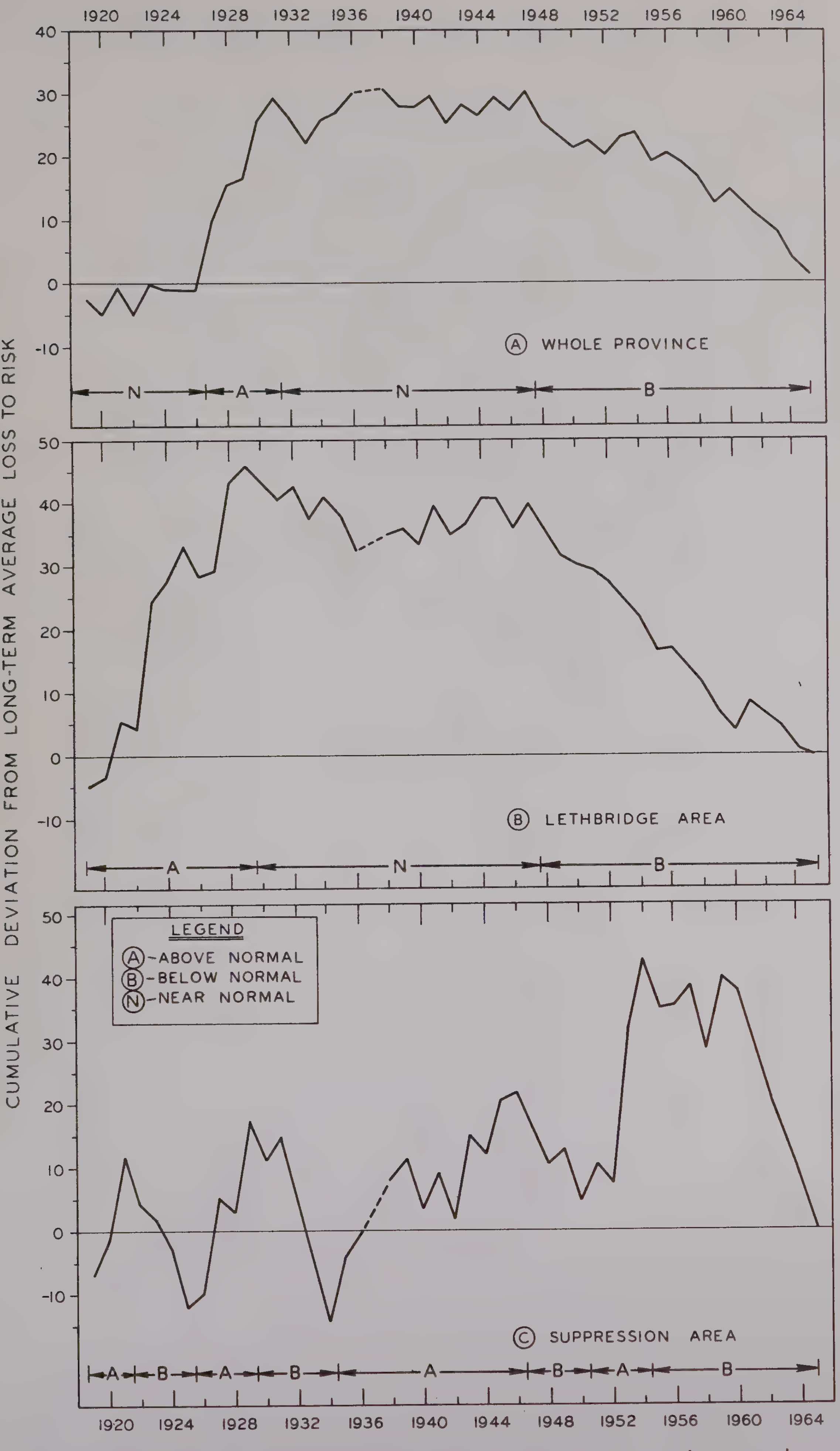

Figure 7 Time-series of the cumulative deviation from the normal yearly mean L/R for various regions.